A DISEASE-RELATED APPROACH TO BIOAEROSOLS

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I. What are bioaerosols?
   A. Microorganisms shed by occupants and accumulating in air to unacceptable levels

   B. Microorganisms growing on building substrates and entering the air

   C. Effluents of non-human building occupants

II. Organisms producing bioaerosols
   A. Viruses
      1. Obligate pathogens
         a. Require a living host
         b. Do not grow on artificial substrates

      2. Very small; penetrate most filters

      3. "Simple"; protein coat + nucleic acid

   B. Bacteria
      1. Most are facultative saprophytes
         a. Able to grow outside of living tissue
         b. Many can grow on environmental substrates

      2. Small, usually unicellular, no organized nucleus

      3. Types of bacteria
         a. Gram negative rods
            (1). Environmental sources
            (2). Produce endotoxin as part of cell wall

         b. Gram positive rods
            (1). Environmental and human source
            (2). Some produce endospores

         c. Gram positive cocci
            (1). Human sources
            (2). Usually do not cause airborne disease

         d. Gram positive "mycelial" (actinomycetes)
            (1). Environmental sources
            (2). Produce dry airborne spores

   C. Fungi
      1. Nearly all are saprophytes and occupy environmental reservoirs

      2. Large size range from about 1 um to large, macroscopic fruiting bodies.

3. Types
    a. Unicellular forms (yeasts)
    b. Molds and mildews
    c. Plant disease organisms
    d. Mushrooms

4. Complex cell structure and metabolism
    a. Eukaryotic (like human cells)
    b. Multicellular (hyphae, mycelium, tissues)
    c. Specialized spores for dispersal
    d. Secondary metabolites (mycotoxins)

D. Arthropods
1. Mites
    a. Microscopic (about 100um)
    b. Free living in dust
    c. Fecal particles become airborne

2. Cockroaches
    a. Macroscopic pests
    b. Free living in damp places
    c. Fecal particles, body parts become airborne

E. Birds
1. Human choice exposure
2. Serum, droppings, ?dander airborne

F. Mammals
1. Rats, mice
    a. Pests or laboratory exposure
    b. Urine becomes airborne

2. Dogs, cats
    a. Human choice or laboratory exposure
    b. Saliva, urine become airborne

III. Diseases
A. Contagious disease
1. Infections
    a. Organisms must be alive
    b. Organisms do not cause other diseases

2. Human to human transmission

3. Agents
    a. Viruses
        (1). Examples: Influenza, measles, chicken pox, some colds

        (2). Never grow on inanimate substrates; may survive passage through ventilation systems

        (3). Very small, may not be removed by filtration

    b. Bacteria

(1). Examples: Tuberculosis

(2). Not usually growing on building substrates but may survive on surfaces

(3). Do not grow readily in culture

4. Risk factors
   a. Lack of specific immunity
   b. Dose
   c. Virulence of organism

5. Evaluation
   a. Disease identification/epidemiology
   b. Air and/or source samples not useful

6. Prevention
   a. Vaccination
   b. Avoidance/isolation
   c. Ventilation

B. Environmental-source virulent infections
   1. Type of disease: Infection
      a. Organisms must be alive
      b. Organisms do not cause other diseases

   2. Transmission mode: transmitted from outdoor reservoirs or housed animals

   3. Agents
      a. Rickettsia (Q-fever)
      b. Bacteria (anthrax)
      c. Fungi (Histoplasmosis, Blastomycosis, Coccidioidomyco.

   4. Risk factors
      a. Lack of specific immunity
      b. Dose
      c. Virulence of the organism

   5. Evaluation
      a. Disease identification/epidemiology
      b. Sampling usually not useful

   6. Prevention
      a. Avoidance
      b. Removal of reservoirs

C. Environmental-source opportunistic infections
   1. Type of disease: infection
      a. Organisms must be alive
      b. Organisms may also cause allergic/toxic disease

   2. Transmission mode:
      a. Outdoor reservoirs: cooling towers, compost

b. Indoor reservoirs: water reservoirs, surface growth

3. Agents
   a. Bacteria
      (1). Examples: legionellosis, *Pseudomonas* pneumonia
      (2). Sources: water reservoirs

   b. Fungi
      (1). Examples: cryptococcosis, aspergillosis
      (2). Sources: accumulations of organic material; surface growth on semi-dry substrates

4. Risk factors
   a. Immune system malfunctions
      (1). Disease (AIDS, cancer, etc.)
      (2). Medications (steroids, immunosuppressants)
      (3). Substance "abuse" (smoking, alcohol)

   b. Dose

   c. Virulence

5. Evaluation
   a. Disease identification; epidemiology
   b. Source sampling of potential reservoirs
   c. Air sampling possible for *Aspergillus*

6. Prevention
   a. Removal of reservoirs
   b. Avoidance

D. Hypersensitivity diseases: Asthma, Hay fever
   1. Immune response disease: exposure units do not need to be alive to cause a response.

   2. Transmitted from outdoor and indoor reservoirs

   3. Agents
      a. Fungi (any fungus; ex. *Alternaria, Aspergillus*)

      b. Pollen (air dispersed; ex. grass, ragweed, many trees)

      c. Arthropods (especially indoor pests; ex. mites, cockroaches.

      d. Mammals (especially indoor pets, laboratory animals; ex. dogs, cats, mice, rats)

   4. Risk factors
      a. Genetic

      b. Exposure patterns (differ for development of sensitization and development of symptoms)

      c. Antigenicity

5. Evaluation
   a. Disease identification

   b. Environmental evaluation
      (1) Observation
      (2) Source sampling
      (3) Air sampling

6. Prevention
   a. Avoidance
   b. Remove reservoirs
   c. Desensitization

E. Hypersensitivity diseases: Hypersensitivity pneumonitis

1. Immune response; agents of exposure need not be alive to elicit effect.

2. Transmitted from indoor reservoirs

3. Agents
   a. Bacteria (*Bacillus*, thermophilic actinomycetes)

   b. Fungi (any small-spored fungus, or fungus growing in a water reservoir where antigens can be eluted and sprayed into the air as small droplets; ex. *Penicillium, Cladosporium*).

   c. Birds (serum, droppings)

4. Risk factors
   a. Host risk factors unknown

   b. Exposure levels and patterns

   c. Adjuvants (either intrinsic as in thermophilic actinomycetes, or endotoxin)

   d. Antigenicity

5. Evaluation
   a. Disease identification

   b. Environmental evaluation
      (1). Observation
      (2). Source samples
      (3). Air sampling

6. Prevention
   a. Avoidance
   b. Remove environmental reservoirs

F. Toxicoses

1. Direct cellular toxic effect; exposure units need not be alive.

2. Transmitted from environmental reservoirs either in association with source organisms or as inanimate droplets containing the active metabolite.

3. Agents
   a. Bacteria (Endotoxins, exotoxins)

   b. Fungi (Mycotoxins; ex. *Aspergillus flavus, Stachybotrys atra, Fusarium sporotrichoides*)

4. Risk factors
   a. Direct cellular toxic effect; human dose response is constant

   b. Toxicity

   c. Dose

5. Evaluation
   a. Disease identification

   b. Environmental evaluation
      (1). Observation
      (2). Source sampling to identify toxigenic organisms
      (3). Air sampling to verify airborne exposure

6. Prevention
   a. Avoidance
   b. Removal of environmental reservoirs

G. Airborne microbial contamination that probably does not cause disease
   1. Agents include human-source bacteria (e.g., *Micrococcus, Staphylococcus epidermidis, Streptococcus salivarius)*

   2. Grow readily in culture and constitute the usually-measured bacterial flora on indoor air samples.

   3. Accumulate when per person ventilation is inadequate

H. Sick building syndrome
   1. Symptoms include: headache, dizziness, nausea, eye irritation, lethargy, chest tightness, sinus congestion

   2. Hypothetical causes include: inadequate outdoor air ventilation which causes accumulation of volatile organic compounds, fungal and/or bacterial toxins, other biogenic odors, comfort and stress factors.

   3. Risk: unknown

   4. Evaluation:
      a. Observation
      b. Measurements (ventilation)
      c. Sampling (CO_2, etc.)

IV. General approach to building investigations involving bioaerosols

A. Do symptoms match a microbially induced disease? If not, check for adequate ventilation or other kinds of contaminants.

B. Is the epidemic human to human transmission problem? If so, check for adequate per person fresh air.

C. Is the disease legionellosis? (diagnosed, serotyped)

1. Is there more than one case? Remember: a single case does not necessarily implicate the work environment. Most *Legionella* exposure probably occurs in the home.

2. Look for source of aerosolized contaminated water; culture and compare serotypes.

a. Air sampling is not effective

b. *Legionella* is a common organism. Finding it does not imply disease or even risk.

D. Is there an obvious microbial contamination problem?

1. Walk through and look for water problems, obvious mold growth, or microbial slimes; musty or locker-room odors; damp fabric (carpet, drapes, furniture).

2. Check air intake location for possible outdoor sources (e.g., compost piles, cooling towers, construction)

3. Obvious microbial problems should generally be remedied without sampling. Regardless of sampling results you will recommend remediation.

E. General protocol for microbial sampling

1. Use the ACGIH Guidelines

2. Source samples can document the presence of contamination in suspected reservoirs, and the nature of the organisms. Examine samples visually and microscopically, and culture with 24 hours on definitive media for fungi, bacteria and actinomycetes at appropriate temperatures.

3. Use both cultural and particulate methods for air sampling

4. Use good quality volumetric devices; never rely on gravity collections.

5. Data analysis

a. There are no published numeric guidelines

b. Acceptable levels depend on the sampling method

c. Acceptable levels depend on the organism

(1). Thermophilic actinomycetes should not be present

(2). *Stachybotrys atra* should not be present.

(3). Pattern of taxon prevalence should parallel that in outdoor air for the season.

d. "Grab" samples may seriously misrepresent bioaerosol status of an environment.